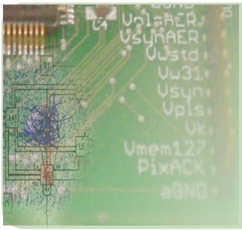

STATE-DEPENDENT SENSORY PROCESSING IN DISTRIBUTED NETWORKS OF VLSI SPIKING NEURONS

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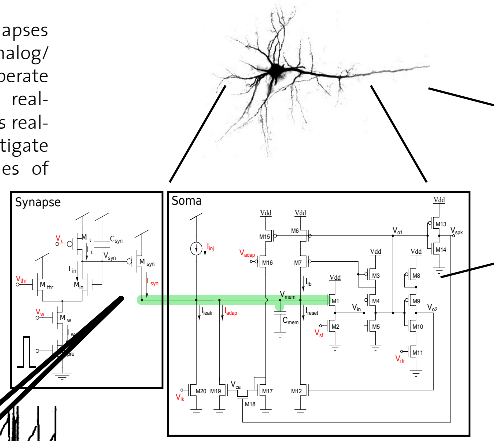
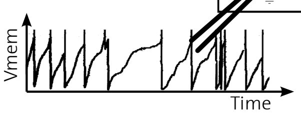
Silicon Integrate & Fire Neurons

Silicon neurons and synapses are low-power hybrid analog/ digital circuits which operate in parallel, respond in real-time, and can be used as real-time tools to investigate computational properties of neural systems.

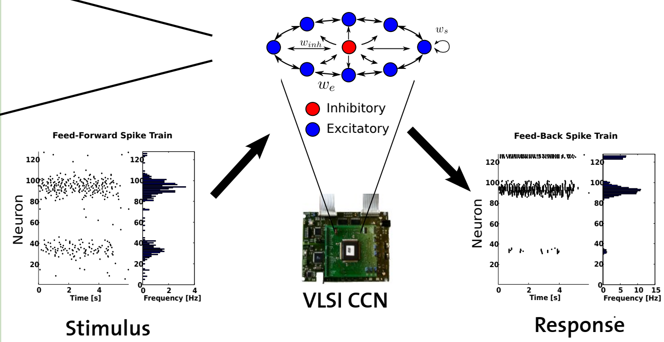




Schematics of a silicon VLSI Neuron [Indiveri et al. IEEE TNM 2006]

Soft Winner-Take-All in recurrently connected Integrate & Fire Neurons (I&F)

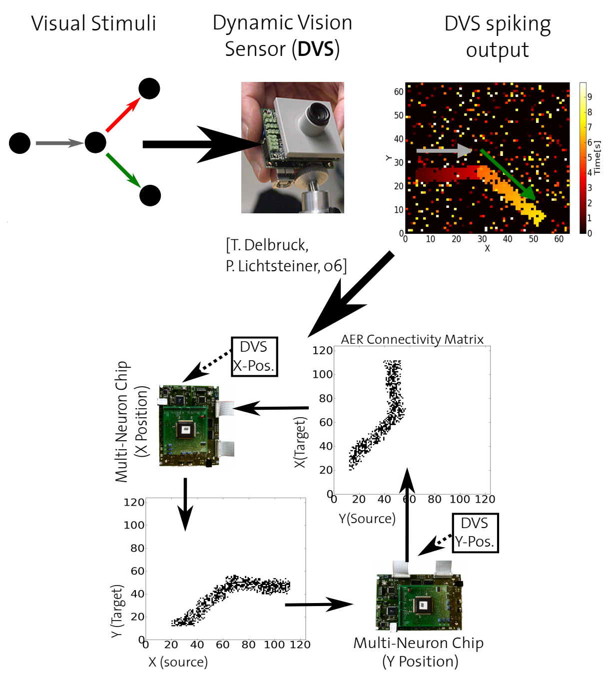
Silicon neurons can be recurrently coupled in an excitatory and inhibitory fashion in order to mimic the patterns of activity observed in the cortex, leading to a soft Winner-Take-All computation (See Below)



Configuring a Multi-Chip setup for tracking visual stimuli

We present a method for configuring a setup containing multi–neuron chips implementing a soft WTA for exploiting persistent activity states to process the sensory output of an event–based vision sensor in a state–dependent fashion. The resulting network accepts or refuses the trajectory of a stimulus on the basis of a previous observation. In [Neftci et al. ISCAS 2010], we give analytical groundings for these principals

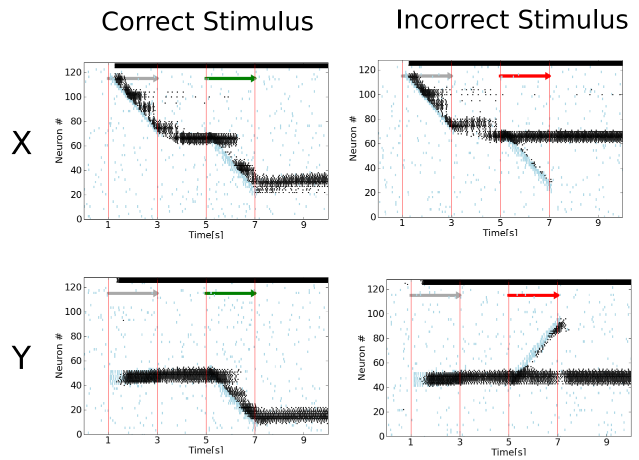
Using the Address-Event-Representation (AER), our chips can be arbitrarily coupled together to form large multi-chip networks.
The setup consists in two multi-neuron chips which were stimulated by an AER asynchronous 64x64 Dynamic Vision Sensor (DVS) that responds to temporal contrast (See Below).



The column–wise activity of the DVS was retinotopically mapped to the first multi–neuron chip and the row–wise activity was retinotopically mapped to the second multi– neuron chip (see **Above**). The connectivity between both multi–neuron chips was set during an initialization procedure where the DVS was stimulated in the absence of recurrent connectivity between both chips.

Results

(**Below**) Raster plots of both multi-neuron chips during stimulus presentation. The red lines indicate the different phases of the stimulus, indicated by the colored arrows. The blue dots represent the input from the DVS.



Correct stimulus, Green arrow: target moving to the lower–right.
From t=0s to t = 1s, we observe no activity because the target is stationary. Between t = 1s and t = 3s (gray arrow) the target moves horizontally to the right, and the DVS starts to stimulate the multi–neuron chips. At t = 3s, the target makes a 2s pause. Between t = 5s and t = 7s the target moves to the lower–right (represented by the green arrow) and finally stops. **Even in the absence of sensory stimulation during 3s < t < 5s and t > 7s, we observe that the activity in the neurons persist.**

Incorrect stimulus: Red arrow: target moving to the upper–right.
During 3s < t < 5s, the input stimulates a combination of populations which are not not allowed to activate, given the relations between both chips. **As a result, the network resists the drift induced by the input. After t > 7s, the activity remains at its last valid location.**

Conslusion & Outlook: The recurrent AER connectivity between the two chips was set in an initial phase and gave rise to persistent activity states, that were stable even in the absence of external stimuli. The system was able to accept or reject the trajectory of the target, without precise timing of its motion or direction of movement.
This illustrates state–dependent processing of an event–based visual input using a network of recurrently connected VLSI circuits implementing soft WTA.

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